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(54) **AIR SUPPLY SYSTEM FOR FUEL CELL**

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(58) **Field of Search** 429/34, 26; 418/83, 418/84

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(57) **ABSTRACT**

An air supply system for a fuel cell is disclosed, in which a compression chamber (17) of an air supply mechanism (GS) is adapted to supply air to a fuel cell (FC). A liquefaction unit (14) acting as a water supply mechanism (WS) supplies water to the air supply mechanism (GS) to seal and cool the compression chamber (17). The liquefaction chamber (14) separates water from the exhaust gas discharged from the fuel cell (FC) and supplies the water to the air supply mechanism (GS). The air supply mechanism (GS) and the liquefaction unit (14) are integrated with each other.

14 Claims, 15 Drawing Sheets

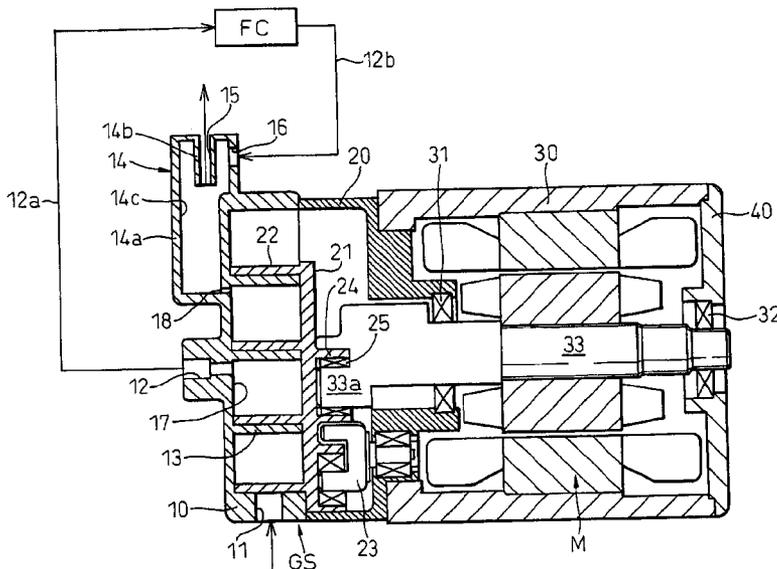


Fig.2

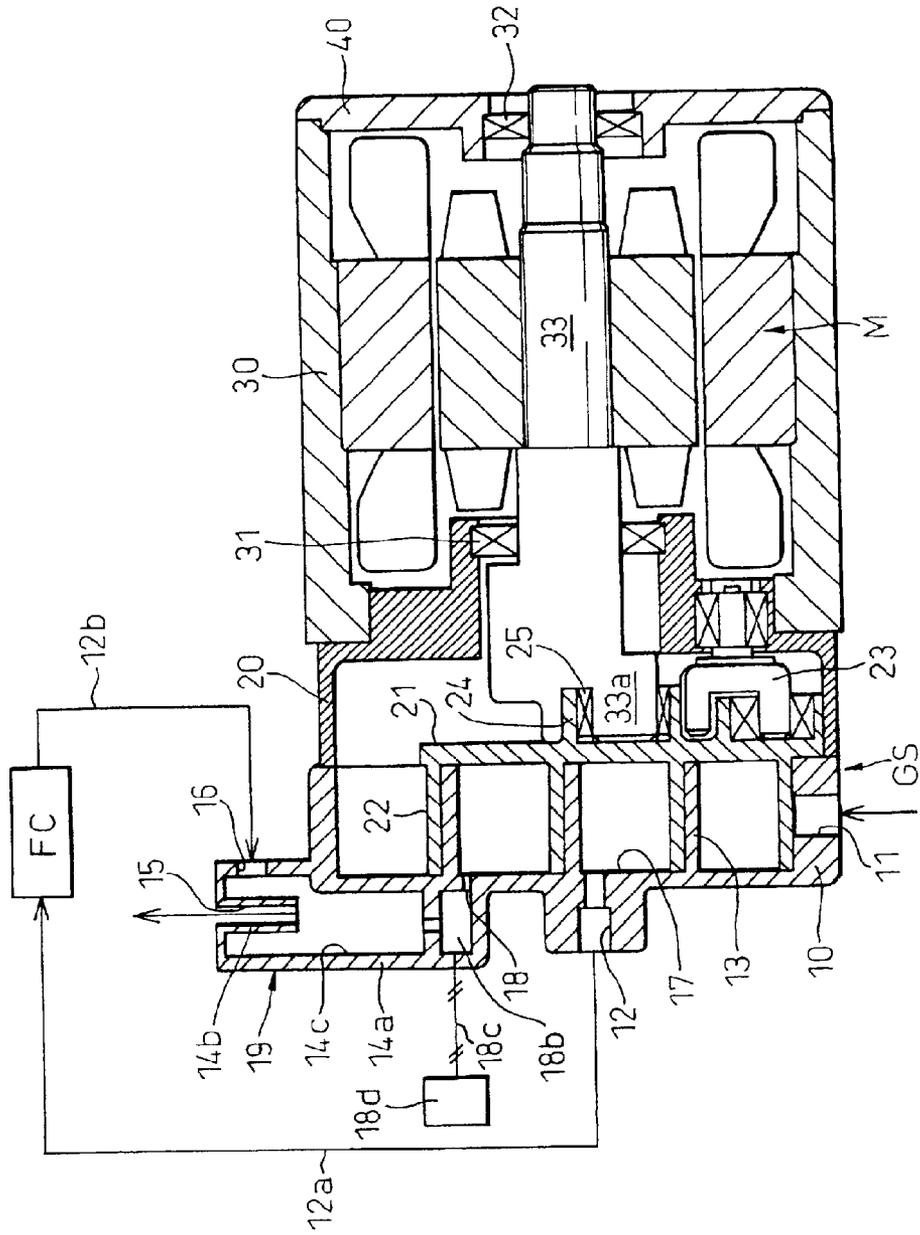


Fig.3

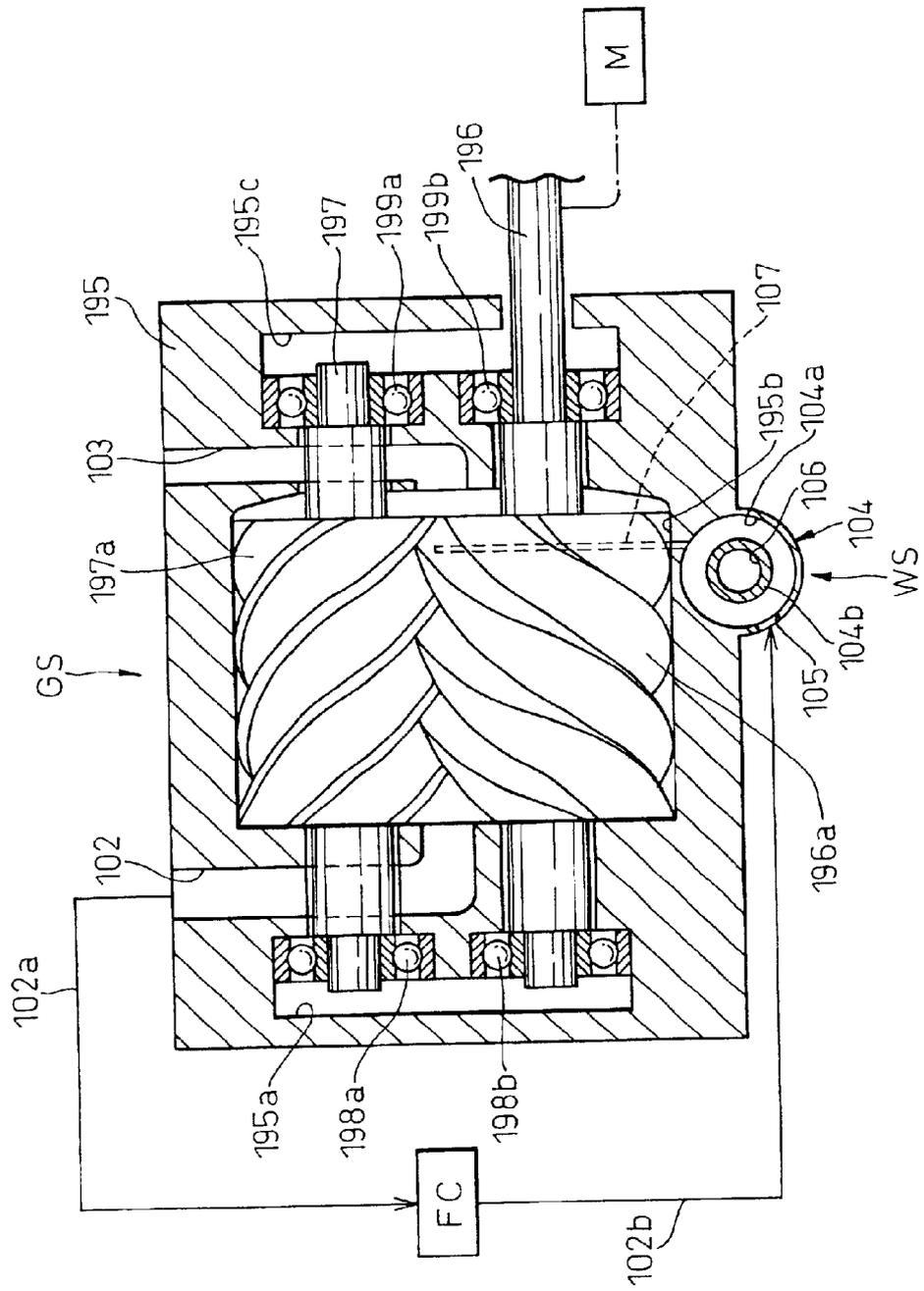


Fig. 5

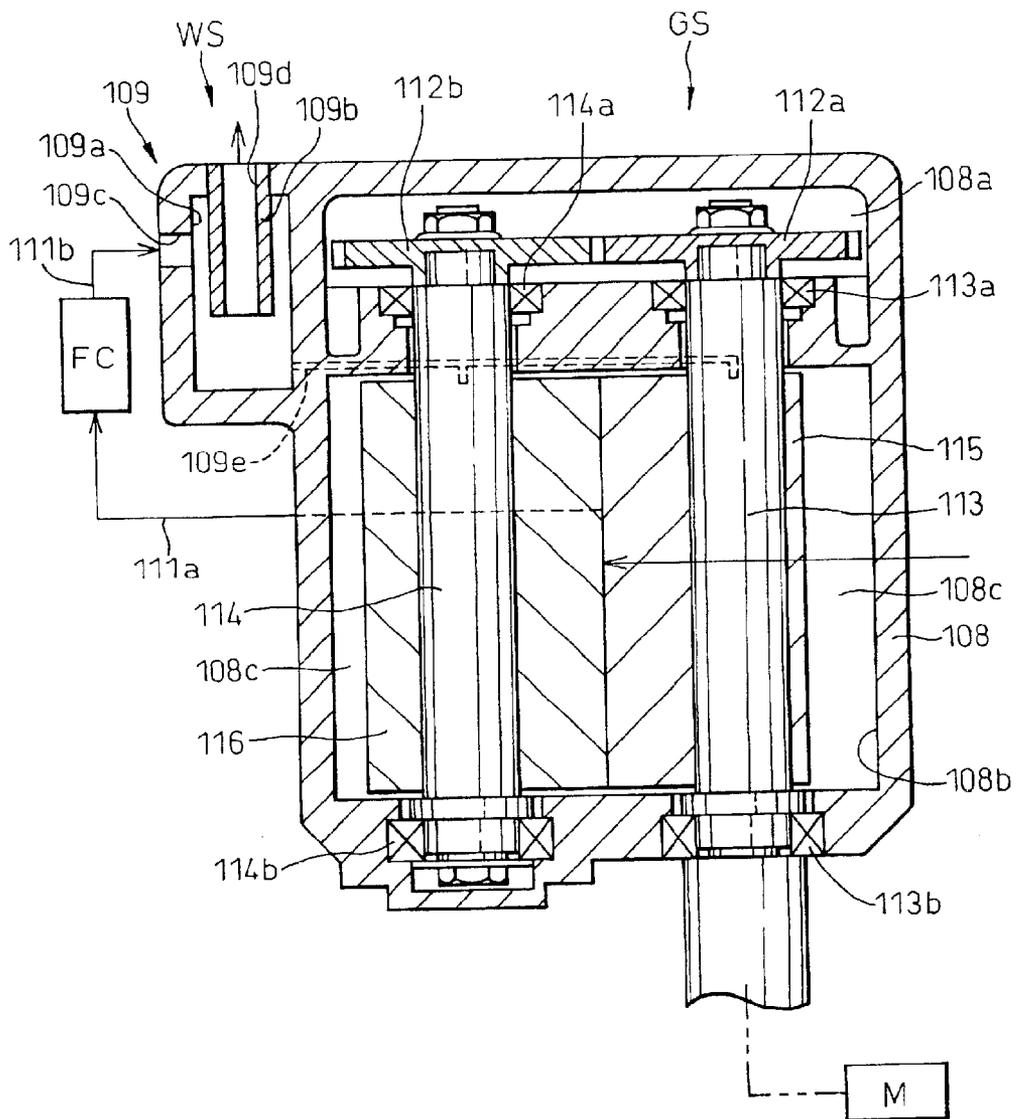


Fig.6

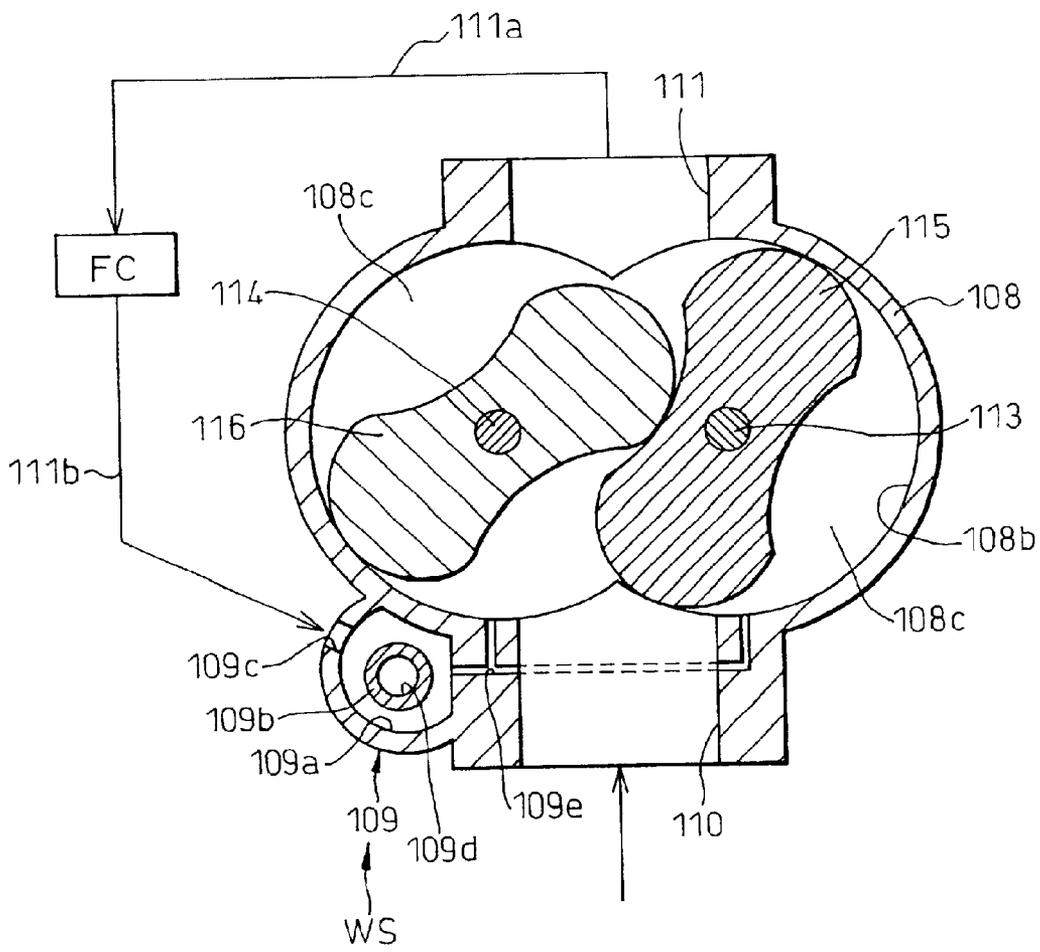


Fig.8

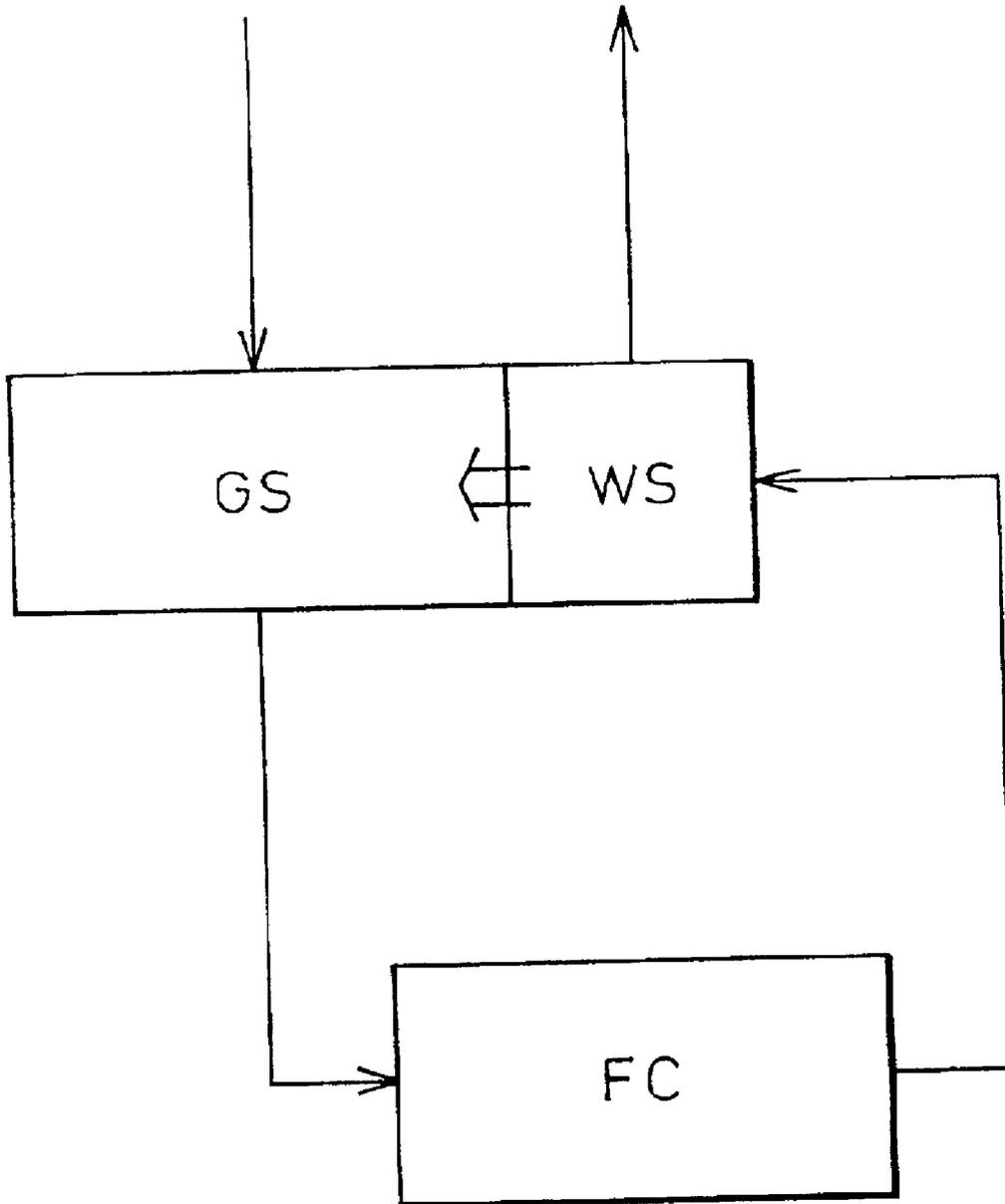


Fig.10

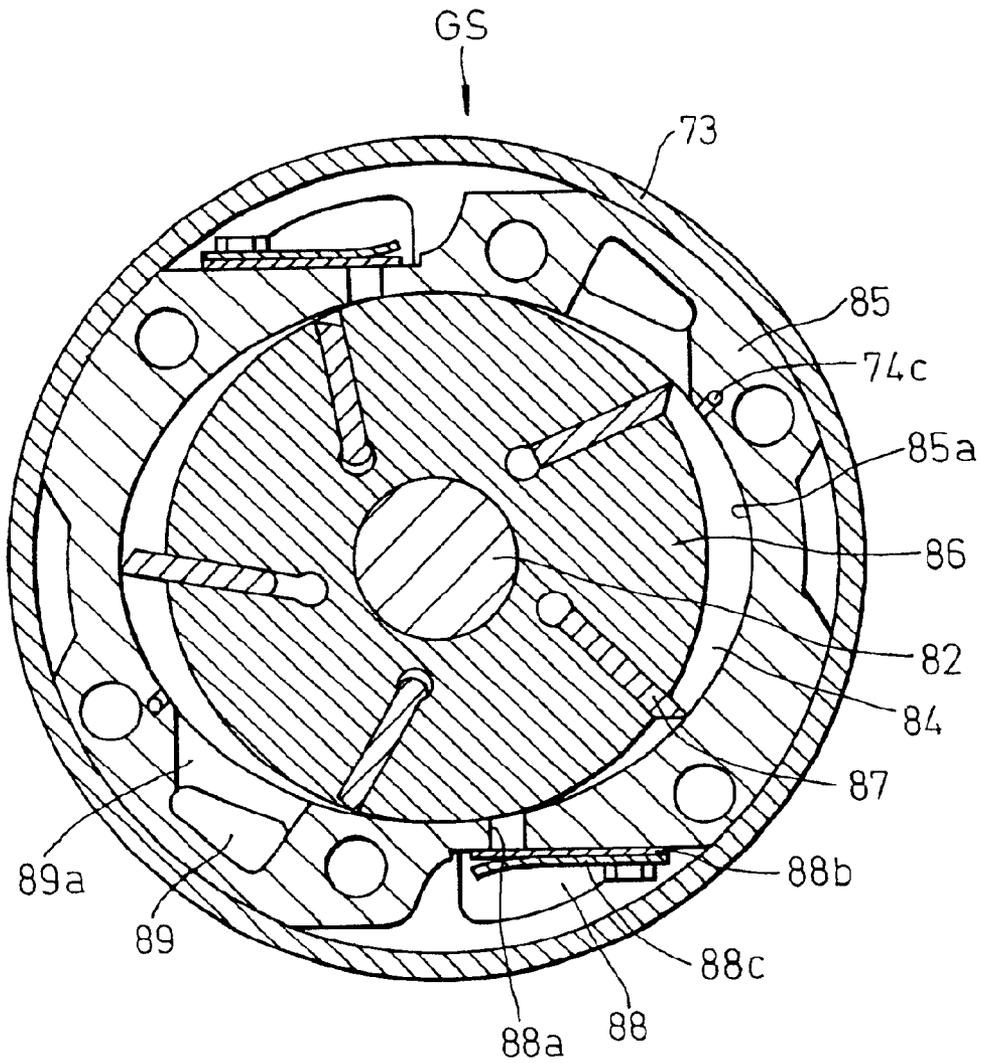


Fig. 11

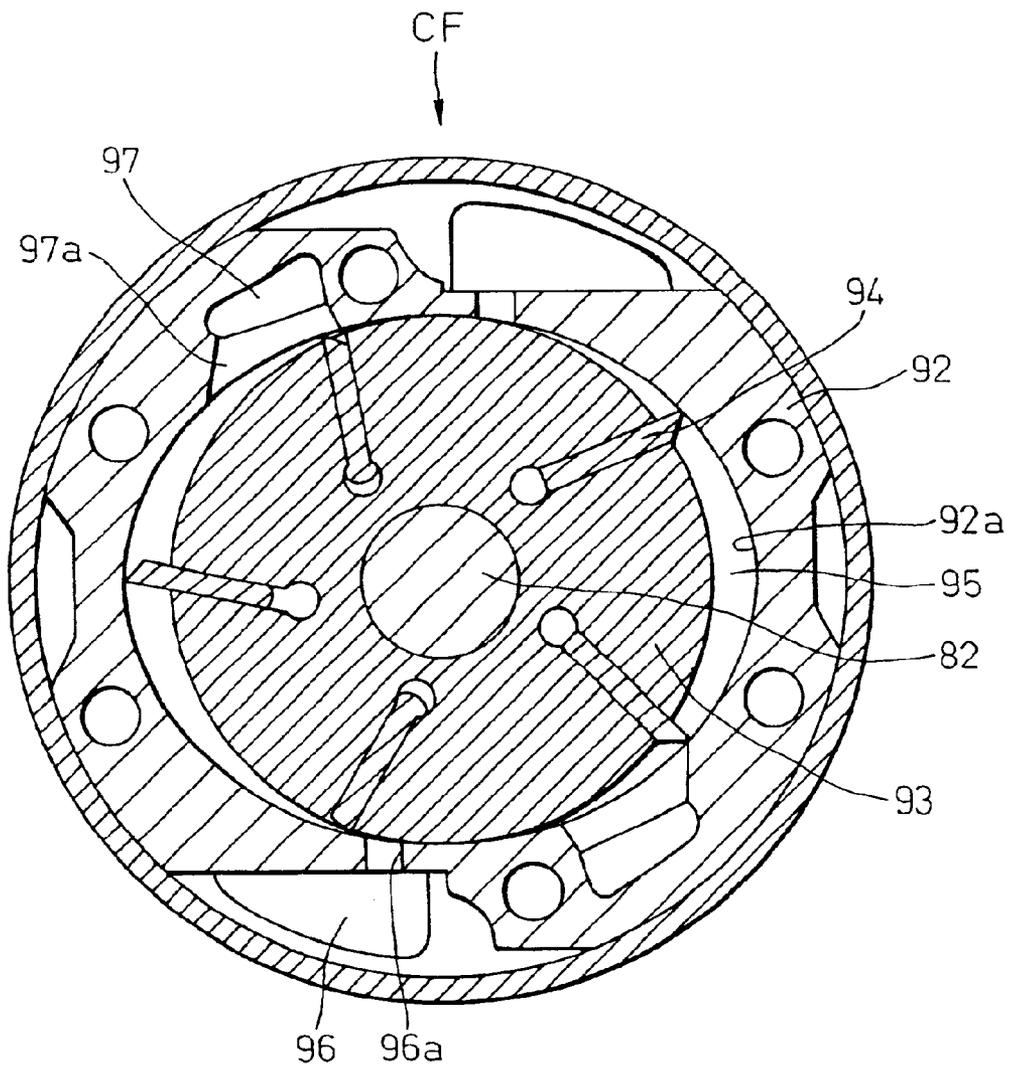


Fig.12

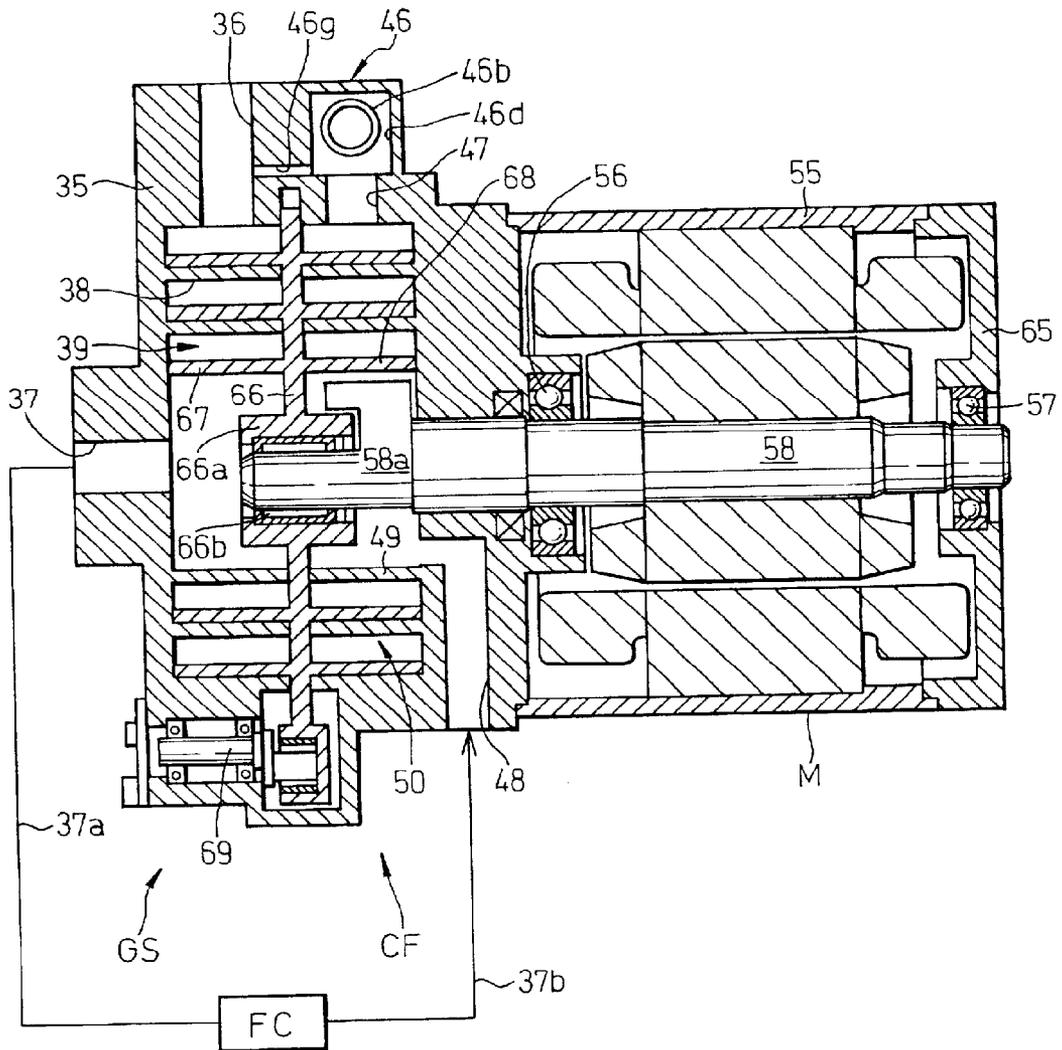


Fig.13

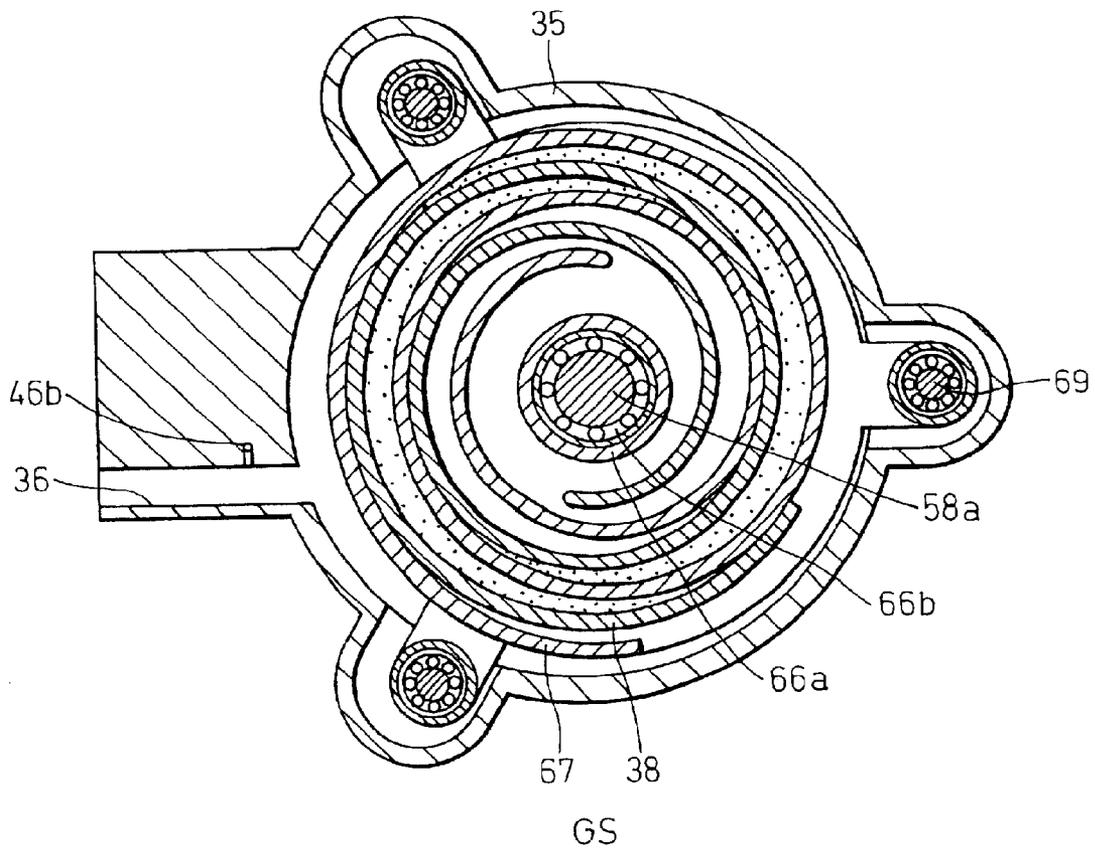


Fig. 14

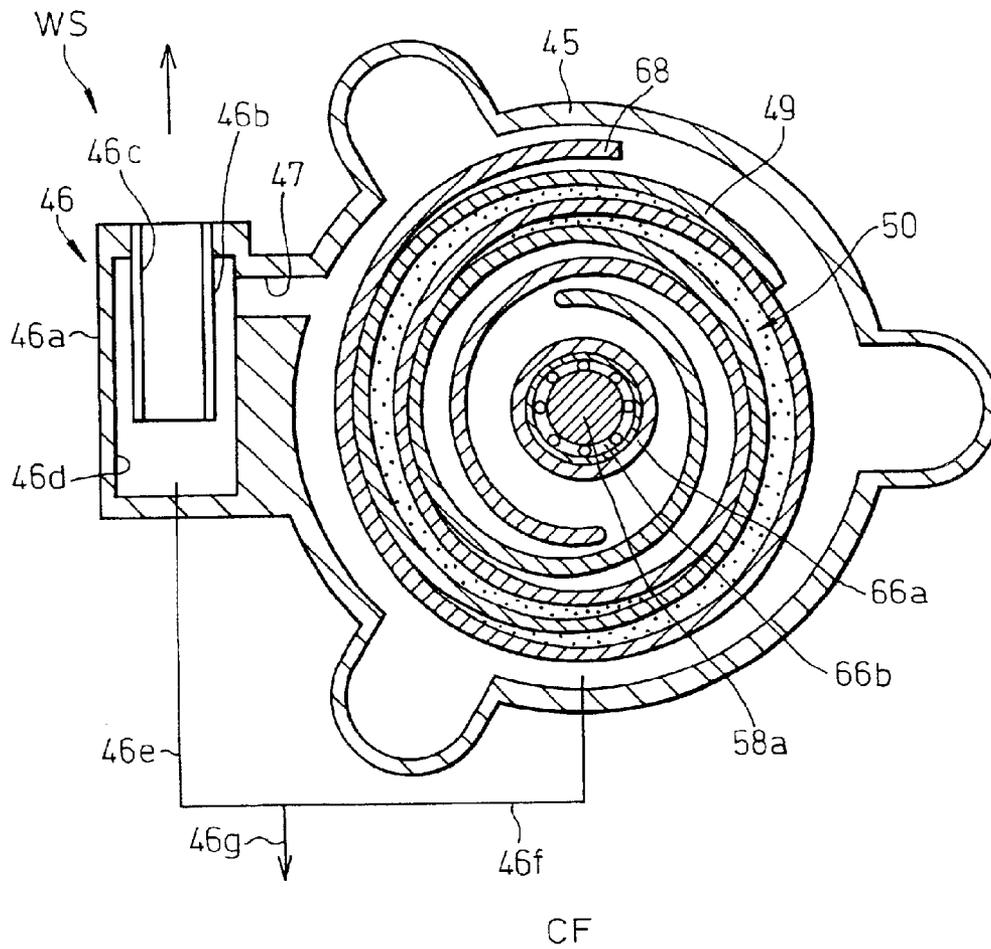
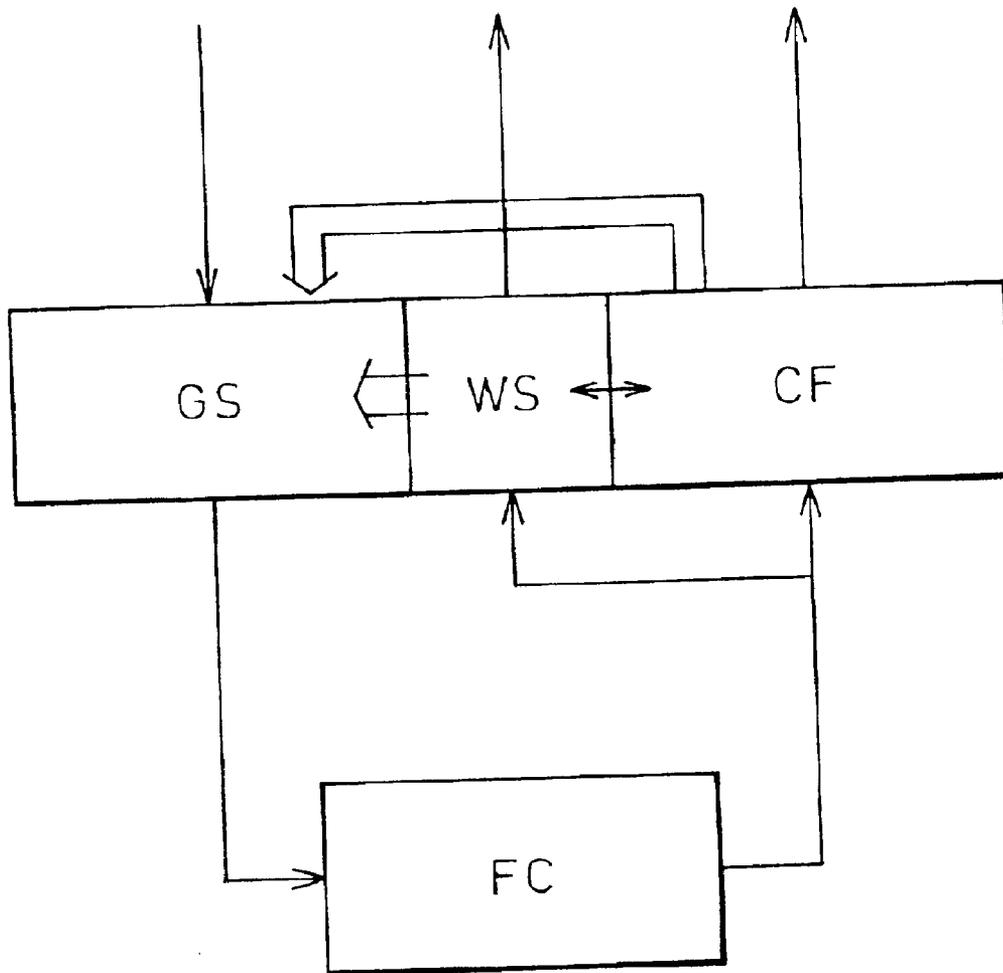


Fig.15



AIR SUPPLY SYSTEM FOR FUEL CELL**BACKGROUND OF THE INVENTION****1. Field of the Invention**

The present invention relates to an air supply system for a fuel cell used in a fuel cell system.

2. Description of the Related Art

A fuel cell system used for an automotive vehicle includes a fuel cell and an air supply system for a fuel cell connected to the fuel cell (Japanese Unexamined Patent Publication No. 7-14599).

Specifically, a fuel supply pipe and an air supply pipe for supplying the fuel and the air, respectively, are connected upstream of the fuel cell. The air supply pipe is opened to the atmosphere through a compressor driven by a motor, so that the air constituting an oxygen-containing gas in the atmosphere is compressed to a predetermined pressure in the compression chamber of the compressor and supplied to the fuel cell. This compressor makes up an air supply mechanism as a part of the air supply system for the fuel cell and the compression chamber of the compressor constitutes an air supply chamber.

An air discharge pipe for discharging into the atmosphere the exhaust gas constituting the air from which oxygen is consumed in the fuel cell is connected downstream of the fuel cell. The air discharge pipe is opened to the atmosphere through a regenerator configured integrally with the compressor and, therefore, the exhaust gas is expanded in the regeneration chamber thereby to drive the regenerator and thus assist the compressor. The exhaust gas in the air discharge pipe is produced by reaction in the fuel cell, and therefore contains water vapor generated in the fuel cell as well as water vapor from the atmosphere. For this reason, the air supply system for the fuel cell includes a liquid separator in addition to the compressor and the regenerator described above. The liquid separator is connected with an air discharge pipe, and separates the water vapor as water from the exhaust gas passing through the air discharge pipe. The water thus produced is stored in a storage vessel and then injected into the compression chamber of the compressor by a pump to seal and cool the compression chamber. The liquid separator, the storage vessel and the pump make up a water supply mechanism as the remaining part of the air supply system for the fuel cell. In this way, the air supply system for the fuel cell improves the compression efficiency of the compressor and hence the power generation efficiency of the fuel cell.

In the conventional air supply system for a fuel cell described above, however, the compressor and the regenerator, though integrated with each other, are separated from the liquid separator, the storage vessel and the pump. Therefore, the structure is not sufficiently simplified, thereby increasing the production cost of the air supply system for the fuel cell. Especially, the need for the liquid separator tends to complicate the system. This air supply system for the fuel cell, if used for an automotive vehicle, is unavoidably disadvantageous from the viewpoint of mountability due to its large size.

SUMMARY OF THE INVENTION

The present invention has been developed to solve this problem and the object thereof is to provide a sufficiently simplified air supply system for a fuel cell which is low in production cost and which is capable of maintaining the power generation efficiency of the fuel cell.

According to one aspect of the present invention, there is provided an air supply system for a fuel cell comprising an air supply mechanism including an air supply chamber capable of supplying an oxygen-containing gas to a fuel cell and a water supply mechanism for supplying water to the air supply mechanism to close and cool the air supply chamber, wherein the water supply mechanism supplies water to the air supply mechanism by separating it from the exhaust gas discharged from the fuel cell, and the air supply mechanism is integrated with the water supply mechanism.

In the air supply system for a fuel cell according to this aspect of the invention, the water supply mechanism separates water from the exhaust gas discharged from the fuel cell, and the water is supplied to the air supply mechanism. Specifically, the water supply mechanism functions as a liquid separator, a storage vessel and a pump in the prior art. Since the water supply mechanism is integrated with the air supply mechanism, the structure is sufficiently simplified and therefore the production cost of the air supply system for the fuel cell can be reduced. Especially the air supply system for the fuel cell, if used with an automotive vehicle, can be advantageously mounted on the vehicle due to its simplicity.

In this way, with the air supply system for the fuel cell according to the invention, the power generation efficiency of the fuel cell can be maintained while sufficiently simplifying the structure, and reducing the production cost, of the fuel cell.

According to another aspect of the invention, there is provided an air supply system for a fuel cell wherein at least the drive source such as a motor for driving the air supply mechanism is also integrated with the air supply mechanism and the water supply mechanism. By doing so, the structure is further simplified for a further reduced production cost. This simplified structure also improves the mountability of the air supply system for the fuel cell, if used in an automotive vehicle.

The air supply mechanism includes an air supply chamber capable of supplying an oxygen-containing gas to the fuel cell. The air supply mechanism can be of any of various types including a scroll, a vane, a screw, a root and a piston type. The scroll-type air supply mechanism, the vane-type air supply mechanism and the piston-type air supply mechanism, in which the volume of the closed space is reduced, implement the air supply chamber as a compression chamber. The screw-type air supply mechanism and the root-type air supply mechanism, on the other hand, do not reduce the volume of the closed space but supply the gas under pressure and, therefore, implement the air supply chamber as a pressurized supply chamber.

The air supply mechanism is desirably capable of changing the amount of the oxygen-containing gas per unit power. By doing so, the amount of the oxygen-containing gas supplied to the fuel cell can be changed as required, and wasteful power consumption can be avoided for a further improved mechanical efficiency.

The water supply mechanism can include a liquefying unit for liquefying, into water, the water vapor contained in the exhaust gas discharged from the fuel cell. The liquefying unit can be of a centrifugal separation type in which a turbulent flow of the exhaust gas is generated by centrifugal force and collides with the peripheral surface for liquefying the water vapor into water.

On the other hand, the water supply mechanism can include a regeneration mechanism unit for assisting the air supply mechanism by expanding the exhaust gas. The regeneration mechanism includes a regeneration chamber capable

of supplying the water generated by expansion of the exhaust gas to the air supply mechanism. Specifically, the exhaust gas is reduced in temperature by expansion, and the water vapor contained in it is liquefied into water. Thus, the regeneration mechanism can function as a water supply mechanism. By doing so, water is supplied from the regeneration chamber of the regeneration mechanism to the air supply mechanism to close and cool the air supply chamber. Therefore, the regeneration mechanism is easily integrated with the air supply mechanism, and a need for a liquid separator is eliminated. In this way, the system is further simplified and the production cost of the air supply system for a fuel cell can be further reduced. In this case, the power generated by the regeneration mechanism adds to the power for activating the air supply mechanism. Specifically, the regeneration mechanism recovers the residual energy from the exhaust gas of the fuel cell and adds it to the power of the air supply mechanism. As a result, wasteful power consumption is avoided for a further improved mechanical efficiency.

The water supply mechanism, desirably, can change the amount of water supplied. By doing so, the amount of water supplied to the air supply mechanism can be changed as required, and therefore the optimum power generation efficiency can be realized.

The air supply mechanism and the regeneration mechanism can be configured to operate on different drive shafts and can be connected to each other through a power transmission mechanism. As an alternative, the air supply mechanism and the regeneration mechanism can be configured to operate on the same drive shaft. The drive shaft is desirably shared by the motor or the like drive source. By doing so, the simplified structure can further reduce the production cost.

The drive source can be an internal combustion engine instead of a motor. In the case where both the motor and the internal combustion engine are used as drive sources, an electromagnetic clutch is desirably arranged between the internal combustion engine and at least the drive shaft of the air supply mechanism. In the case where this air supply system for the fuel cell is mounted on a hybrid car or the like, the mode for driving at least the air supply mechanism by the motor and the mode for driving at least the air supply mechanism by the internal combustion engine can be switched other easily.

Also, the air supply mechanism and the regeneration mechanism are desirably configured to operate on the same drive shaft. The resulting simplified structure can further reduce the production cost.

At least one of the air supply mechanism and the regeneration mechanism is desirably of a scroll type. In that case, the effects described above can be exhibited while at the same time making it possible to achieve a quiet and light-weight air supply system for the fuel cell.

According to yet another aspect of the invention, there is provided an air supply system for a fuel cell comprising an air supply mechanism and a regeneration mechanism of scroll type, wherein the air supply mechanism preferably includes a housing, one surface of the side plate orbiting about a drive shaft and a first spiral member protruded from the same one surface, and the regeneration mechanism preferably includes a housing, the other surface of the same side plate and a second spiral member protruded from the same other surface. In this air supply system for the fuel cell, the side plate from which the first and second spiral members protrude can be shared by the air supply mechanism and the regeneration mechanism of scroll type. As a result, the

structure can be considerably simplified and the production cost can be reduced. Also, the total axial length including the drive source such as the motor can be reduced, thereby attaining a superior mountability on a automotive vehicle, for example.

Further, at least one of the air supply mechanism and the regeneration mechanism is desirably of vane type. In that case, the air supply system for the fuel cell, though somewhat less quiet, can achieve an operation and effects similar to those of scroll type.

According to a further aspect of the invention, there is provided an air supply system for a fuel cell comprising an air supply mechanism and a regeneration mechanism of vane type, wherein the air supply mechanism includes a housing, a first rotor rotated by a drive shaft and a first vane adapted to protrude in a radial direction from the first rotor, and the regeneration mechanism includes a housing, a second rotor rotating on the same axis as the first rotor and a second vane adapted to protrude in a radial direction from the second rotor. In this air supply system for the fuel cell, the first rotor and the second rotor have the same structure, and therefore the production cost is reduced.

The present invention will be more fully understood with reference to the accompanying drawings and the preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal sectional view of an air supply system for a fuel cell according to a first embodiment of the invention.

FIG. 2 is a longitudinal sectional view of an air supply system for a fuel cell according to a second embodiment of the invention.

FIG. 3 is a longitudinal sectional view of an air supply system for a fuel cell according to a third embodiment of the invention.

FIG. 4 is a cross sectional view of an air supply system for a fuel cell according to the third embodiment of the invention.

FIG. 5 is a longitudinal sectional view of an air supply system for a fuel cell according to a fourth embodiment of the invention.

FIG. 6 is a cross sectional view of an air supply system for a fuel cell according to the fourth embodiment of the invention.

FIG. 7 is a longitudinal sectional view of an air supply system for a fuel cell according to a fifth embodiment of the invention.

FIG. 8 is a diagram schematically showing the structure of an air supply system for a fuel cell according to the first to fifth embodiments of the invention.

FIG. 9 is a longitudinal sectional view of an air supply system for a fuel cell according to a sixth embodiment of the invention.

FIG. 10 is a cross sectional view of an air supply system for a fuel cell according to a sixth embodiment of the invention.

FIG. 11 is a cross sectional view of an air supply system for a fuel cell according to the sixth embodiment of the invention.

FIG. 12 is a longitudinal sectional view of an air supply system for a fuel cell according to a seventh embodiment of the invention.

FIG. 13 is a cross sectional view of an air supply system for a fuel cell according to the seventh embodiment of the invention.

FIG. 14 is a cross sectional view of an air supply system for a fuel cell according to the seventh embodiment of the invention.

FIG. 15 is a diagram schematically showing the structure of an air supply system for a fuel cell according to the sixth and seventh embodiments of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The first to seventh embodiments of the present invention will be described below with reference to the accompanying drawings.

Embodiment 1

In the air supply system for a fuel cell according to a first embodiment of the invention, as shown in FIG. 1, a center housing 20 is coupled to the rear end of a front housing 10, and a motor housing 30 is coupled to the rear end of the center housing 20. A rear housing 40 is coupled to the rear end of the motor housing 30. The front housing 10, the center housing 20, the motor housing 30 and the rear housing 40 make up a housing assembly.

An air suction hole 11 is opened to the atmosphere on the radial side of the front housing 10, and an air discharge hole 12 is formed at the axial front end of the central portion of the front housing 10. The air discharge hole 12 is connected to an air supply pipe 12a communicating with the oxygen-containing gas supply side of the fuel cell FC. A fixed spiral member 13 is protruded rearward in axial direction in the front housing 10.

A liquefaction unit 14 of a centrifugal separation type constituting a water supply mechanism WS is arranged at the front outer periphery of the front housing 10. The liquefaction unit 14 includes a vertically extending outer cylinder portion 14a with a bottom and forming an internal liquefaction chamber 14c, and an inner cylinder portion 14b protruded downward from the upper end of the outer cylinder portion 14a along the same axis as the latter. The outer cylinder portion 14a is formed therethrough with an air introduction hole 16 at a position facing the outer peripheral surface of the inner cylinder portion 14b. The air introduction hole 16 is connected with an air discharge pipe 12b communicating with the gas discharge side of the fuel cell FC. The interior of the inner cylinder portion 14b is formed with an air discharge hole 15 communicating with the atmosphere.

A side plate 21 extending in radial direction is interposed between the front housing 10 and the center housing 20. A movable spiral member 22 is protruded forward in axial direction from the side plate 21. The movable spiral member 22 of the side plate 21 is in mesh with a fixed spiral member 13 of the front housing 10.

In this way, a compression chamber is formed as a feeder chamber closed by the front housing 10 and the side plate 21. These members make up an air supply mechanism GS of a scroll type. The air suction hole 11 communicates with the compression chamber 17 not yet closed, while the air discharge hole 12 communicates with the closed compression chamber 17 after the final compression operation. A water supply hole 18 communicating with the closed compression chamber 17 is formed through the bottom portion of the liquefaction chamber 14c.

An antirotation mechanism 23 is arranged between the front housing 10, the center housing 20 and the side plate 21. A boss 24 protruding axially rearward is formed on the central portion of the side plate 21.

A drive shaft 33 is rotatably supported through bearing units 31, 32 on the center housing 20 and the rear housing

40, while a motor M constituting a drive source including the drive shaft 33 is arranged in the motor housing 30. A crank pin 33a is protruded eccentrically from the forward end of the drive shaft 33, and rotatably inserted into the boss 24 of the side plate 21 through a bearing unit 25.

In this way, the air supply mechanism GS and the liquefaction unit 14 are integrated with each other and with the motor M.

In the air supply system for a fuel cell configured as described above, when the drive shaft 33 is driven by the motor M the side plate orbits with the rotation thereof restricted by the antirotation mechanism 23. As a result, the volume of the compression chamber 17 of the air supply mechanism GS is gradually reduced, so that the air constituting the oxygen-containing gas in the atmosphere is introduced into the compression chamber 17 from the air suction hole 11, and after being compressed to high pressure in the compression chamber 17, supplied to the fuel cell FC through the air supply pipe 12a from the air discharge hole 12. In the fuel cell FC, the oxygen in the air is consumed and the air remaining as an exhaust gas is supplied from the air discharge pipe 12b through the air introduction hole 16 to the liquefaction unit 14.

The air that has passed the fuel cell FC has already reacted, and therefore contains the water vapor generated in the fuel cell FC as well as the water vapor from the atmosphere. As a result, in the liquefaction unit 14, the air discharged from the fuel cell generates a turbulent flow around the inner cylinder portion 14b by centrifugal force, and this turbulent flow collides with the inner peripheral surface of the liquefaction chamber 14c thereby to liquefy the water vapor, contained in the air, into water. The remaining air is released into the atmosphere from the air discharge hole 15.

In this way, water stays in the liquefaction chamber 14c, and this water is supplied to the closed compression chamber 17 through the water supply hole 18. As a result, the air supply system for the fuel cell according to the first embodiment functions as the liquid separator, the storage vessel and the pump in the prior art. This liquefaction unit 14 has a sufficiently simplified structure, included in the air supply mechanism GS integrated with the motor M, and is low in production cost. Therefore, it is suitably used in an automotive vehicle from the viewpoint of mountability.

With the air supply system for the fuel cell according to the first embodiment, it is seen that a sufficiently simplified structure can reduce the production cost while maintaining the power generating efficiency of the fuel cell FC.

Embodiment 2

The air supply system for a fuel cell according to a second embodiment comprises a liquefaction unit 19 shown in FIG. 2. The liquefaction unit 19 includes a valve 18b formed in the bottom portion of the outer cylinder portion 14a and adapted to open/close the water supply hole 18. The valve 18b is connected to a controller 18d by a lead wire 18c, and the water supply hole 18 can be opened or closed by the valve 18b in response to a predetermined signal. The remaining parts of the configuration are the same as the corresponding ones of the first embodiment.

In the air supply system for a fuel cell according to the first embodiment, the amount of water supplied in the liquefaction unit 14 changes with the weight based on the amount stored in the outer cylinder portion 14a, the inner diameter of the water supply hole 18 and the pressure in the compression chamber 17. In the air supply system for the fuel cell according to the second embodiment, in contrast, the amount of water supplied to the compression chamber 17

can be adjusted by the controller **18d**. In the air supply system for a fuel cell according to the second embodiment, therefore, the compression chamber **17** can be steadily sealed and cooled, thereby making it possible to stabilize the power generation efficiency of the fuel cell FC.

The functions and effects of the other parts are the same as the corresponding ones of the first embodiment.

Embodiment 3

The air supply system for a fuel cell according to a third embodiment of the invention comprises, as shown in FIG. 3, a housing **195** including therein a first bearing unit chamber **195a**, a screw chamber **195b** and a second bearing unit chamber **195c** arranged in that order from the front side of the housing **195**. The first bearing unit chamber **195a**, the screw chamber **195b** and the second bearing unit chamber **195c** have a drive shaft **196** and a driven shaft **197** extending in parallel to each other. The drive shaft **196** and the driven shaft **197** are rotatably supported by the first bearing units **198a**, **198b** and the second bearing units **199a**, **199b** in the first bearing unit chamber **195a** and the second bearing unit chamber **195c**, respectively. A drive screw **196a** having the section thereof shown in FIG. 4 is fixed on the drive shaft **196**, and a driven screw **197a** having the section thereof shown in FIG. 4 is fixed on the driven shaft **197**. The drive screw **196a** and the driven screw **197a** are in mesh with each other. A pressured supply chamber **195d** constituting an air supply chamber is formed of the screw chamber **195b** of the housing **195**, the drive screw **196a** and the driven screw **197a**. As shown in FIG. 3, the drive shaft **196** is arranged through the rear wall of the housing **195** and connected to the motor M constituting a drive source through a power transmission mechanism not shown. Thus, the air supply mechanism GS of a screw type is configured.

An air suction hole **103** open to the atmosphere is formed between the screw chamber **195b** and the second bearing unit chamber **195c**. This air suction hole **103** communicates between the drive screw **196a** and the driven screw **197a** at the rear side of the screw chamber **195b**.

Also, an air discharge hole **102** is opened between the first bearing unit chamber **195a** and the screw chamber **195b**, and communicates between the drive screw **196a** and the driven screw **197a** at the front side of the screw chamber **195b**. The air supply pipe **102a** communicating with the air supply side of the fuel cell FC is connected to the air discharge hole **102**.

Further, as shown in FIG. 4, the housing **195** has an air introduction hole **105** formed therethrough and is also formed with a liquefaction chamber **104a** communicating with the air introduction hole **105**. The air introduction hole **105** is connected to an air discharge pipe **102b** communicating with the gas discharge side of the fuel cell FC. A cylinder member **104b** having an outer peripheral surface facing the air introduction hole **105** is arranged in the liquefaction chamber **104a**. The interior of the cylinder member **104b** has an air discharge hole **106** communicating with the atmosphere. Also, a water supply hole **107** communicating between the bottom portion of the liquefaction chamber **104a** and the closed pressured supply chamber **195d** of the air supply mechanism GS is formed through the housing **195**. In this way, the liquefaction chamber **104** constituting a water supply mechanism WS is configured, and the air supply mechanism GS is integrated with the liquefaction unit **104**.

In the air supply system for a fuel cell configured as described above, once the drive shaft **196** is driven by the motor M, the drive screw **196a** and the driven screw **197a** rotate. As a result, the air constituting an oxygen-containing gas in the atmosphere is introduced into the pressured supply

chamber **195d** from the air suction hole **103** and sent to the air discharge hole **102** under pressure. The air sent under pressure is supplied to the fuel cell FC through the air supply pipe **102a**. In the fuel cell FC, the oxygen in the air is consumed and the air remaining as an exhaust gas is supplied through the air discharge pipe **102b** to the liquefaction unit **104**.

In the liquefaction unit **104**, the air discharged from the fuel cell FC generates a turbulent flow by centrifugal force and by colliding the inner peripheral surface of the liquefaction chamber **104a** with the turbulent flow, the water vapor contained therein is liquefied into water. Water is stored in the liquefaction chamber **104a** in this way, and supplied to the closed pressured supply chamber **195d** through the water supply hole **107**. The remaining air is released into the atmosphere through the air discharge hole **106**.

As described above, the air supply system of this type for a fuel cell can exhibit effects similar to those of the first embodiment.

Embodiment 4

The air supply system for a fuel cell according to a fourth embodiment includes a gear chamber **108a** and a rotor chamber **108b** in the housing **108** as shown in FIG. 5. A gear **112a** and a gear **112b** in mesh with each other are arranged in the gear chamber **108a**. A drive shaft **113** passing through the rotor chamber **108b** is fixed to the gear **112a**, and is rotatably supported through the bearing units **113a**, **113b**. The drive shaft **113** passes through the bottom surface of the housing **108** and is connected to the motor M constituting a drive source through a power transmission mechanism not shown. A driven shaft **114** parallel to the drive shaft **113** passes through the rotor chamber **108b**, is fixed to the gear **112b** and is rotatably supported through the bearing units **114a**, **114b**. Rotors **115**, **116**, having a cocoon-shaped section are fixed on the drive shaft **113** and the driven shaft **114**, 90 degrees apart in phase from each other, as shown in FIG. 6. In this way, a pressurized supply chamber **108c** constituting a closed air supply chamber is formed of the gear chamber **108a** of the housing **108** and the rotors **115**, **116**. These component parts make up a root-type air supply mechanism GS.

An air suction hole **110** open to the atmosphere is formed on one side of the housing **108**, and an air discharge hole **111** is formed on the other side of the housing **108** far from the air suction hole **110** with the rotors **115**, **116** therebetween. The air discharge hole **111** is connected to an air supply pipe **111a** communicating with the oxygen-containing gas supply side of the fuel cell FC.

As shown in FIG. 5, an air introduction hole **109c** is formed through the housing **108**, which also has formed therein a liquefaction chamber **109a** communicating with the air introduction hole **109c**. The air introduction hole **109c** is connected to an air discharge pipe **111b** communicating with the gas exhaust side of the fuel cell FC. A cylinder member **109b** having an outer peripheral surface in opposed relation to the air introduction hole **109c** is arranged in the liquefaction chamber **109a**. The interior of the cylinder member **109b** has an air discharge hole **109d** communicating with the atmosphere. A water supply hole **109e** is also formed in the housing **108** for communicating between the bottom portion of the liquefaction chamber **109a** and the closed pressured supply chamber **108c** of the air supply mechanism GS. In this way, the liquefaction unit **109**, of a centrifugal separation type and constituting the water supply mechanism WS, is configured integrally with the air supply mechanism GS.

In the air supply system for the fuel cell configured as described above, the rotors **115**, **116** are rotated when the drive shaft **113** is driven by the motor M. As a result, air, constituting an oxygen-containing gas, is introduced into the pressured supply chamber **108c** from the air suction hole **110** and sent to the air discharge hole **111** under pressure. The air thus sent under pressure is supplied to the fuel cell FC through the air supply pipe **111a**. In the fuel cell FC, the oxygen in the air is consumed, and the air that remains as an exhaust gas is supplied to the liquefaction unit **109** through the air discharge pipe **111b**.

In the liquefaction unit **109**, a turbulent flow, of the air discharged from the fuel cell FC, is generated around the cylinder member **109b** by centrifugal force and it collides with the inner peripheral surface of the liquefaction chamber **109a** thereby to liquefy the water vapor contained therein. This water is stored in the liquefaction chamber **109a** and supplied through the water supply hole **109e** to the closed pressured supply chamber **108c**. The remaining air is released into the atmosphere through the air discharge hole **109d**.

In this way, the air supply system for the fuel cell according to this embodiment can exhibit effects similar to the first embodiment.

Embodiment 5

In the air supply system for the fuel cell according to a fifth embodiment, as shown in FIG. 7, a cup-shaped front housing **118** is coupled to the front end of the cylinder block **117** formed with a plurality of cylinder bores **117a** and an axial central holes **117b**, and a rear housing **123** is coupled to the rear end of the cylinder block **117** with a valve plate **120**, etc. held therebetween. A motor housing **121** is fixed on the rear end of the rear housing **123**. The cylinder block **117**, the front housing **118**, the rear housing **123** and the motor housing **121** make up a housing assembly.

The front housing **118** is also formed with an axial hole **118a**. In the crank chamber **124** formed of the front end of the cylinder block **117** and the front housing **118**, a drive shaft **128** is rotatably supported through a bearing unit **125** and a shaft seal unit **126** in the axial hole **118a** and also through a bearing unit **127** in the axial hole **117b** of the cylinder block **117**.

In the crank chamber **124**, a lug plate **130** is fixed on the drive shaft **128**. The bearing unit **129** is interposed between the lug plate **130** and the front housing **118**. A pair of arms **131** protrude rearward from the lug plate **130**, and a guide hole **131a** having a cylindrical inner surface is formed through each arm **131**. The drive shaft **128** is inserted through a through hole **132a** of a swash plate **132**, and an inclination angle-reducing spring **133** is interposed between the swash plate **132** and the lug plate **130**. On the other hand, a return spring **143** is arranged, with a snap ring, on the drive shaft **128** slightly behind the swash plate **132**.

A pair of guide pins **132b** at the front end of the swash plate **132** protrude toward each arm **131**, and a guide portion **132c** having a spherical outer surface rotatable and slidable in the guide hole **131a** is formed at the forward end of each guide pin **132b**.

Pistons **135**, supported by a corresponding pair of shoes **134**, are engaged with the peripheral portion of the swash plate **132**. Each piston **135** is accommodated in a corresponding cylinder bore **117a**.

A suction chamber **123a** and a discharge chamber **123b** are formed inside the rear housing **123**. The suction chamber **123a** communicates with each cylinder bore **117a** by way of an suction port **144** formed through the valve plate **120** and the discharge chamber **123b** communicates with each cyl-

inder bore **117a** by way of the discharge port **145** formed through the valve plate **120**.

The liquefaction chamber **148** is formed in the rear housing **123**. The discharge chamber **123b** is connected to the air supply pipe **146** communicating with the oxygen-containing gas supply side of the fuel cell FC, and the air discharge pipe **147** communicating with the liquefaction chamber **148** is connected to the gas discharge side of the fuel cell FC. A cylinder member **149** having an outer peripheral surface in opposed relation to the air discharge pipe **147** is arranged in the liquefaction chamber **148**. The interior of the cylinder member **149** is formed with an air discharge hole **149a** communicating with the atmosphere. A water supply hole **150** communicating between the bottom portion of the liquefaction chamber **148** and the suction chamber **123a** is formed through the rear housing **123**. The rear housing **123** has accommodated therein a control valve **151** for changing the stroke of the piston **135** and the inclination angle of the swash plate **132** in accordance with the differential pressure between the internal pressure of the crank chamber **124** and the suction pressure in the suction chamber **123a** thereby to control the compression capacity. In this way, the liquefaction unit **151** of a centrifugal separation type constituting the water supply mechanism WS is configured, and the air supply mechanism GS is integrated with the liquefaction unit **151**.

A motor M including the drive shaft **128** supported by the bearing unit **152** is configured in the motor housing **121**. In this way, the air supply mechanism GS and the liquefaction unit **151** are integrated with each other and also with the motor M.

Further, an electromagnetic clutch MC is arranged on the drive shaft **128** protruded forward from the front housing **118**. Specifically, a pulley **138** is rotatably mounted on the front housing **118** through the bearing unit **122**, and an excitation coil **119** is fixed in the pulley **138**. A belt, not shown, connected with the engine EG constituting a drive source is wound on the pulley **138**. Also, a hub **136** is fixed on the drive shaft **128**, and an armature **142** facing the pulley **138** is mounted, movably back and forth on the hub **136** through the spring plate **141**.

In the air supply system for the fuel cell configured as described above, when the drive shaft **128** is driven by the engine EG or the motor M, the swash plate **132** rotates synchronously, so that the piston **135** reciprocates in the cylinder bore **117a** through shoes **134**. As a result, a compression chamber is formed as an air supply chamber between the cylinder bore **117a** and the head of the piston **135**. When the compression chamber is in a suction stage, the air constituting the oxygen-containing gas is introduced from the suction chamber **123a**, while, when the compression chamber is in a compression stage, the air constituting the high-pressure oxygen-containing gas is discharged from the compression chamber to the discharge chamber **123b**. The air discharged to the discharge chamber **123b** is supplied to the fuel cell FC through the air supply pipe **146**. In the fuel cell FC, the oxygen in the air is consumed, and the air remaining as an exhaust gas is supplied from the air discharge pipe **147** to the liquefaction unit **151**.

In the liquefaction unit **151**, a turbulent flow of the air, discharged from the fuel cell FC, is generated around the cylinder member **149** by centrifugal force and it collides with the inner peripheral surface of the liquefaction chamber **148** thereby to liquefy the water vapor contained in the air. The remaining air is discharged into the atmosphere by way of the air discharge hole **149a**. In this way, water is stored in the liquefaction chamber **148** and supplied through the water supply hole **150** to the suction chamber **123a**.

In this way, the air supply system for the fuel cell according to this embodiment can exhibit functions and effects similar to those of the first embodiment.

The air supply system for the fuel cell according to this embodiment also employs the engine EG in addition to the motor M as a drive source, and has an electromagnetic clutch MC arranged on the drive shaft 128. In the case where the air supply system is mounted in a hybrid car or the like, therefore, the mode for driving the air supply mechanism GS with the motor M and the mode for driving the air supply mechanism GS with the engine EG can be easily switched.

As described above, according to the first to fifth embodiments of the invention, as shown in FIG. 8, the oxygen-containing gas is supplied from the air supply mechanism GS to the fuel cell FC, and the exhaust gas, after consumption of the oxygen therein in the fuel cell FC, is supplied to the water supply mechanism WS. The air supply mechanism GS and the water supply mechanism WS are integrated with each other.

Embodiment 6

In the air supply system for the fuel cell according to a sixth embodiment, as shown in FIG. 9, a cylindrical first center housing 71 is coupled to the rear end of a cup-shaped front housing 70, and a radially extending front plate 72 is fixedly interposed between the front housing 70 and the first center housing 71. Also, a cylindrical second center housing 73 is coupled to the rear end of the first center housing 71, and a radially extending first center plate 74 is fixedly interposed between the first center housing 71 and the second center housing 73. Further, a radially extending second center plate 75 is fixed at the rear end of the second center housing 73, and a cylindrical motor housing 76 is coupled to the rear end of the second center plate 75. The rear end of the motor housing 76 is closed by a rear plate 77. A housing assembly is made up of the front housing 70, the first and second center housings 71, 73, the front plate 72, the first and second center plates 74, 75, the motor housing 76 and the rear plate 77. The drive shaft 82 is rotatably supported by the bearing units 78 to 81 on the front plate 72, the first and second center plates 74, 75 and the rear plate 77.

An air suction hole 73a open to the atmosphere and an air discharge hole 73b are formed in the peripheral surface of the second center housing 73. The air discharge hole 73b is connected to an air supply pipe 83 communicating with the oxygen-containing gas supply side of the fuel cell FC.

A first cylinder block 85 for defining an elliptical rotor chamber 85a at the central portion thereof is accommodated in the second center housing 73, as shown in FIG. 10. A first rotor 86 having a circular section fixed on the drive shaft 82 is arranged rotatably in the rotor chamber 85a, and a plurality of first vanes 87 are radially arranged in a manner adapted to protrude from the outer peripheral surface of the first rotor 86. In this way, a compression chamber 84 constituting an air supply chamber surrounded by the first and second center plates 74, 75, the first cylinder block 85, the first rotor 86 and a pair of the first vanes 87 is formed in the rotor chamber 85a.

As shown in FIG. 9, an air suction chamber 89 communicating with the air suction hole 73a is formed in the first cylinder block 85. The air suction chamber 89 communicates with the compression chamber 84 by way of the suction port 89a. In similar fashion, an air discharge chamber 88 communicating with the air discharge hole 73b is formed in the first cylinder block 85, and communicates also with the compression chamber 84 by way of the discharge port 88a. A discharge reed valve 88b for closing the discharge port 88a is arranged in the air discharge chamber 88,

and a retainer 88c is arranged on the outside of the discharge reed valve 88b. Thus, a vane-type air supply mechanism GS is configured.

Further, as shown in FIG. 9, a primary air introduction hole 71b is formed in the peripheral surface of the first center housing 71. The primary air introduction hole 71b is connected with an air discharge pipe 91 communicating with the gas discharge side of the fuel cell FC. The front plate 72 is formed with a liquefaction chamber 72a communicating with the primary air introduction hole 71b. A cylinder member 90 having an outer peripheral surface in opposed relation to the primary air introduction hole 71b is arranged in the liquefaction chamber 72a. The interior of the cylinder member 90 makes up a primary air discharge hole 90a. In this way, a liquefaction unit 100 of a centrifugal separation type is configured.

Also, the first center housing 71, as shown in FIG. 11, has accommodated therein a second cylinder block 92 for defining an elliptical rotor chamber 92a at the central portion thereof. A second rotor 93 having an elliptical section fixed on the drive shaft 82 is rotatably arranged also in the rotor chamber 92a. A plurality of second vanes 94 are arranged in a manner adapted to protrude radially from the outer peripheral surface of the second rotor 93. Thus, in the rotor chamber 92a, a regeneration chamber 95 is defined by the front plate 72, the first center plate 74, the second cylinder block 92, the second rotor 93 and a pair of the second vanes 94.

As shown in FIG. 9, a secondary air discharge hole 71a open to the atmosphere is formed in the peripheral surface of the first center housing 71. An air discharge chamber 97 communicating with the secondary air discharge hole 71a is formed in the second cylinder block 92, and communicates with the regeneration chamber 95 through the discharge port 97a. In similar fashion, an air supply chamber 96 communicating with the primary air discharge hole 90a is formed in the second cylinder block 92, and communicates with the regeneration chamber 95 by way of the supply port 96a. In this way, a vane-type regeneration mechanism CF is configured.

A first water supply hole 99a communicating with the closed compression chamber 84 of the air supply mechanism GS is formed in the bottom portion of the liquefaction chamber 72a through the front plate 72, the second cylinder block 92 and the first center plate 74. In a similar fashion, a second water supply hole 99b communicating with the closed compression chamber 84 of the air supply mechanism GS through the first water supply hole 99a is formed in the bottom portion of the air discharge chamber 97 through the first center plate 74. In this way, the liquefaction unit 100 of centrifugal separation type is configured. The regeneration mechanism CF and the liquefaction unit 100 make up a water supply mechanism WS.

Also, as shown in FIG. 9, a motor M constituting a drive source including the drive shaft 82 is configured in the space surrounded by the second center plate 75, the motor housing 76 and the rear plate 77.

In this way, the air supply mechanism GS, the regeneration mechanism CF and the liquefaction unit 100 are integrated with each other and also with the motor M.

In the air supply system for the fuel cell configured as described above, when the drive shaft 82 is driven by the motor M, the first rotor 86 and the second rotor 93 rotate. As a result, the compression chamber 84 of the air supply mechanism GS gradually decreases in volume, so that the air in the atmosphere is introduced into the compression chamber 84 through the air suction chamber 89 from the air

suction hole **73a**. After being compressed to high pressure in the compression chamber **84**, the air is supplied to the fuel cell FC from the air discharge chamber **88** through the air discharge hole **73b** and the air supply pipe **83**. In the fuel cell FC, the oxygen in the air is consumed and the air remaining as an exhaust gas is supplied to the liquefaction unit **100** from the air discharge pipe **91** through the primary air introduction hole **71b**.

In the liquefaction chamber **100**, a turbulent flow of the air discharged from the fuel cell FC is generated around the cylinder member **90** by centrifugal force and collides with the inner peripheral surface of the liquefaction chamber **72a** thereby to liquefy the water vapor contained in the air. In this way, water is stored in the liquefaction chamber **72a** and is supplied through the first water supply hole **99a** to the closed compression chamber **84**. The remaining air is supplied through the primary air discharge hole **90a** to the air supply chamber **96** of the regeneration mechanism CF.

The air in the air supply chamber **96** is led to the regeneration chamber **95**. The air in the regeneration chamber **95** tends to expand so that the volume of the regeneration chamber **95** gradually increases and the pressure therein is reduced to the atmospheric pressure. In the process, the air temperature in the regeneration chamber **95** decreases by expansion so that the water vapor contained therein is liquefied. As a result, water is stored also in the air discharge chamber **97**, and supplied to the closed compression chamber **84** together with the water in the first water supply hole **99a** through the second water supply hole **99b**. The remaining air is discharged into the atmosphere through the secondary air discharge hole **71a** from the air discharge chamber **97**. In the meantime, power is generated for driving the drive shaft **82** and it assists the power of the motor M for activating the air supply mechanism GS.

In this way, the air supply system for the fuel cell according to this embodiment exhibits an effect similar to that of the first embodiment.

In the air supply system for the fuel cell according to this embodiment, the air supply mechanism GS and the regeneration mechanism CF are configured to operate on the same drive shaft **82** including the motor M. Also, in this air supply system for the fuel cell, the first rotor **86** and the second rotor **93** have the same construction. The resulting simplified structure further reduces the production cost.

The air supply mechanism GS and the regeneration mechanism CF of this air supply system for the fuel cell are of a vane type, and, therefore, are very quiet, though somewhat inferior to the air supply system for the fuel cell according to the first embodiment.

Embodiment 7

In the air supply system for the fuel cell according to a seventh embodiment, as shown in FIG. 12, the motor housing **55** is coupled to the front housing **35**, and the rear housing **65** is coupled to the motor housing **55**. These housings make up a housing assembly.

An air suction hole **36** open to the atmosphere is formed in the radial side of the front housing **35**, and an air discharge hole **37** is formed at the axial front end of the central portion of the front housing **35**. The air discharge hole **37** is connected to the air supply pipe **37a** communicating with the oxygen-containing gas supply side of the fuel cell FC. Also, a first fixed spiral member **38** is protruded rearward axially in the front housing **35**.

A primary air introduction hole **48** is formed in the radial side of the front housing **35**. The primary air introduction hole **48** is connected to the air discharge pipe **37b** communicating with the gas discharge side of the fuel cell FC. On

the other hand, a second fixed spiral member **49** protrudes forward axially in the front housing **35**.

Further, a circular side plate **66** is arranged in the front housing **35**. A first movable spiral member **67** protrudes from the side plate **66** forward axially, while a second movable spiral member **68** protrudes from the side plate **66** rearward axially. The first movable spiral member **67** is in mesh with the first fixed spiral member **38**, and the second movable spiral member **68** is in mesh with the second fixed spiral member **49**. Also, a boss **66a** protrudes longitudinally axially from the central portion of the side plate **66**.

In the motor housing **55**, the drive shaft **58** is rotatably supported on the front housing **35** and the rear housing **65** through the bearing units **56, 57**. An antirotation mechanism **69** is also arranged in the front housing **35**. The motor housing **55** has also configured therein a motor M including the drive shaft **58**. A crank pin **58a** is eccentrically protruded at the front end of the drive shaft **58**. The crank pin **58a** is rotatably inserted into the boss **66a** of the side plate **66** through the bearing unit **66b**.

As shown in FIG. 13, the compression chamber **39** constituting a closed air supply chamber is formed of the front housing **35** and the side plate **66**, thereby making up an air supply mechanism GS of scroll type. The air suction hole **36** communicates with the compression chamber **39** not yet closed, and the air discharge hole **37** communicates with the closed compression chamber **39** after the final compression operation.

As shown in FIG. 14, on the other hand, a closed regeneration chamber **50** is formed of the front housing **35** and the side plate **66**, thereby making up a regeneration mechanism CF of scroll type. The primary air introduction hole **48** communicates with the closed regeneration chamber **50** having the smallest volume.

As shown in FIGS. 12 and 14, a liquefaction unit **46** constituting a water supply mechanism WS is also arranged in the front housing **35**. The liquefaction unit **46**, which has the shape of a vertically extending cylinder with a bottom, includes an outer cylindrical portion **46a** forming an internal liquefaction chamber **46d** and an inner cylindrical portion **46b** arranged on the same axis as the outer cylindrical portion **46a** and protruding downward from the upper end of the outer cylindrical portion **46a**. A secondary air introduction hole **47** is formed in the outer cylindrical portion **46a** at a position facing the outer peripheral surface of the inner cylindrical portion **46b**. The secondary air introduction hole **47** communicates with the regeneration chamber **50** which has ended an expansion and is no longer closed. The interior of the inner cylindrical portion **46b** forms a secondary air discharge hole **46c** communicating with the atmosphere. The regeneration mechanism CF and the liquefaction unit **46** make up a water supply mechanism WS.

A first water supply hole **46e** is formed in the bottom portion of the liquefaction chamber **46d**, and a second water supply hole **46f** is formed in the bottom portion of the regeneration chamber **50**. The first water supply hole **46e** and the second water supply hole **46f** communicate with the closed compression chamber **39** by way of a water supply hole **46g**.

In this way, the air supply mechanism GS, the regeneration mechanism CF and the liquefaction unit **46** are integrated with each other and also with the motor M.

In the air supply system for the fuel cell configured as described above, as shown in FIG. 12, when the drive shaft **58** is driven by the motor M, the side plate **66** orbits while being prevented from rotating by the antirotation mechanism **69**. As a result, as shown in FIG. 13, the compression

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chamber 39 of the air supply mechanism GS gradually decreases in volume, so that the air in the atmosphere is introduced into the compression chamber 39 from the air suction hole 36. The air, after being compressed to a high pressure in the compression chamber 39, is supplied to the fuel cell FC through the air supply pipe 37a from the air discharge hole 37, as shown in FIG. 12. In the fuel cell FC, the oxygen in the air is consumed, and the air remaining as an exhaust gas is supplied to the regeneration chamber 50 of the regeneration mechanism CF through the primary air introduction hole 48 from the air discharge pipe 37b.

The air in the regeneration chamber 50 tends to expand and the volume of the regeneration chamber 50 gradually increases until the pressure therein is reduced to the atmospheric pressure. In the process, the air temperature in the regeneration chamber 50 is reduced by expansion, and the water vapor contained in the air is liquefied. As a result, water is also stored on the bottom portion of the regeneration chamber 50, and supplied to the closed compression chamber 39 through the second water supply hole 46f and the water supply hole 46g. The remaining air is supplied to the liquefaction unit 46 through the primary air discharge hole 47. In the process, power for driving the drive shaft 58 is generated and assists the motor M for activating the air supply mechanism GS.

In the liquefaction unit 46, a turbulent flow of the remaining air is generated around the inner cylindrical portion 46b by centrifugal force and collides with the inner peripheral surface of the liquefaction chamber 46d to liquefy the water vapor contained in the air. In this way, water is stored in the liquefaction chamber 46d and supplied to the closed compression chamber 39 through the first water supply hole 46e and the water supply hole 46g.

As described above, the air supply system for the fuel cell according to this embodiment exhibits similar effects to those of the first and sixth embodiments.

In this air supply system for the fuel cell, the air supply mechanism GS and the regeneration mechanism CF share the side plate 66, and therefore the total axial length including the motor M can be shortened. Also, a superior mountability on an automotive vehicle is exhibited, and an extremely simplified structure reduces the production cost.

The air supply mechanism GS and the regeneration mechanism CF of this air supply system for the fuel cell are of scroll type and therefore both quiet and low weight are realized.

According to the sixth and seventh embodiments of the present invention, as shown in FIG. 15, the oxygen-containing gas is supplied from the air supply mechanism GS to the fuel cell FC, and the exhaust gas after consumption of oxygen contained therein by the fuel cell FC is supplied to the water supply mechanism WS and the regeneration mechanism CF. The air supply mechanism GS, the water supply mechanism WS and the regeneration mechanism CF are integrated with each other.

While the invention has been described by reference to specific embodiments chosen for purposes of illustration, it should be apparent that numerous modifications could be made thereto by those skilled in the art without departing from the basic concept and scope of the invention.

What is claimed is:

1. An air supply system for a fuel cell comprising:

a housing,

an air supply mechanism having an air supply chamber adapted to supply an oxygen-containing gas to a fuel cell and a water supply mechanism for supplying water to said air supply mechanism to seal and cool said air supply chamber,

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wherein said water supply mechanism separates water from the exhaust gas discharged from said fuel cell and supplies said water to said air supply mechanism, said air supply mechanism being integrated with said water supply mechanism, both of said air supply mechanism and said water supply mechanism being formed in said housing, wherein said air supply mechanism communicates with said water supply mechanism through a water supply hole formed in said housing.

2. An air supply system for a fuel cell according to claim 1, wherein said air supply mechanism can change the amount of the oxygen-containing gas per unit power.

3. An air supply system for a fuel cell according to claim 1, wherein said water supply mechanism has a liquefaction unit for liquefying the water vapor contained in the exhaust gas discharged from the fuel cell to thereby produce water.

4. An air supply system for a fuel cell according to claim 3, wherein said liquefaction unit is of a centrifugal separation type and generates a turbulent flow of the exhaust gas by centrifugal force which flow collides with the inner peripheral surface of said liquefaction unit thereby to liquefy the water vapor.

5. An air supply system for a fuel cell according to claim 3, wherein said liquefaction unit is a cylinder shape, and a bottom portion of said liquefaction unit communicates with a compression chamber of said air supply mechanism through a water supply hole and said water is supplied from the bottom portion of said liquefaction to the compression chamber of said air supply mechanism by means of gravity.

6. An air supply system for a fuel cell according to claim 1, wherein said water supply mechanism can change the amount of water supplied.

7. An air supply system for a fuel cell according to claim 1, wherein said housing is formed by a plurality of housing members, and said water supply mechanism and a part of said air supply mechanism are formed in the same housing member.

8. An air supply system for a fuel cell comprising:
a housing,

an air supply mechanism having an air supply chamber adapted to supply an oxygen-containing gas to a fuel cell and a water supply mechanism for supplying water to said air supply mechanism to seal and cool said air supply chamber,

wherein said water supply mechanism separates water from the exhaust gas discharged from said fuel cell and supplies said water to said air supply mechanism, said air supply mechanism being integrated with said water supply mechanism,

wherein said water supply mechanism includes a regeneration mechanism for expanding the exhaust gas discharged from said fuel cell and assisting the power to said air supply mechanism, and said regeneration mechanism includes a regeneration chamber adapted to supply the water generated by the expansion of said exhaust gas to said air supply mechanism.

9. An air supply system for a fuel cell according to claim 8, wherein said air supply mechanism and said regeneration mechanism are configured to operate on the same drive shaft.

10. An air supply system for a fuel cell according to claim 9, wherein at least one of said air supply mechanism and said regeneration mechanism is of a scroll type.

11. An air supply system for a fuel cell according to claim 10, wherein said air supply mechanism and said regeneration mechanism are of a scroll type; said air supply mechanism includes a housing, one surface of a side plate orbited

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by a drive shaft and a first spiral member protruded from said one surface; and said regeneration mechanism includes said housing, the other surface of said side plate and a second spiral member protruded from said other surface.

12. An air supply system for a fuel cell according to claim 9, wherein at least one of said air supply mechanism and said regeneration mechanism is of a vane type.

13. An air supply system for a fuel cell according to claim 12, wherein said air supply mechanism and said regeneration mechanism are of a vane type; said air supply mechanism includes a housing, a first rotor rotated by a drive shaft and a first vane adapted to protrude radially from said first rotor; and said regeneration mechanism includes said housing, a second rotor rotating on the same axis as said first rotor and a second vane adapted to protrude radially from said second rotor.

14. An air supply system for a fuel cell comprising:
a housing,

an air supply mechanism having an air supply chamber adapted to supply an oxygen-containing gas to a fuel cell and a water supply mechanism for supplying water

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to said air supply mechanism to seal and cool said air supply chamber,

wherein said water supply mechanism separates water from the exhaust gas discharged from said fuel cell and supplies said water to said air supply mechanism, said air supply mechanism being integrated with said water supply mechanism, both of said air supply mechanism and said water supply mechanism being formed in said housing,

wherein said water supply mechanism has a liquefaction unit for liquefying the water vapor contained in the exhaust gas discharged from the fuel cell to thereby produce water,

wherein said liquefaction unit is a cylinder shape, and a bottom portion of said liquefaction unit communicates with a compression chamber of said air supply mechanism through a water supply hole and said water is supplied from the bottom portion of said liquefaction to the compression chamber of said air supply mechanism by means of gravity.

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